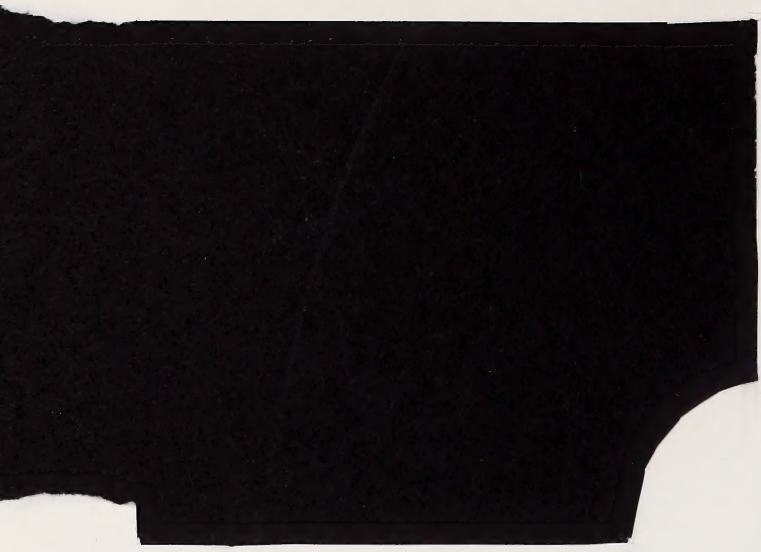
HYDROGEOLOGICAL EVALUATION
PROPOSED SMOKY LAKE
REGIONAL LANDFILL
SW 28-60-17-W4

Alberta
ENVIRONMENT



HYDROGEOLOGICAL EVALUATION
PROPOSED SMOKY LAKE
REGIONAL LANDFILL
SW 28-60-17-W4

Alberta Environment
Environmental Protection Services
Earth Sciences Division
Groundwater Protection Branch

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August, 1987

#568

ABSTRACT

The Groundwater Protection Branch completed a hydrogeological investigation at SW 28-60-17-W4, north of Smoky Lake, Alberta, to determine the suitability of the site for the development of a regional landfill.

The proposed landfill site is located in an area covered with thick till deposited as recessional moraine. A large seasonally wet area is located along the west side of the site, but most of the property is well drained. A saturated sand zone directly overlies bedrock of the Upper Cretaceous Belly River Formation. The sand is protected by between 13 and 22 m of low permeability till. Provided the recommendations contained in this report are followed, there is an area of at least 37 ha (90 acres) which is suitable for landfill development. This area can be increased if trenches are less than 3 m in depth.

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INTRODUCTION

The proposed regional landfill site at SW 28-60-17-W4 is located ten kilometers north of the Town of Smoky Lake (Figure 1). The site is accessible via gravel roads along the south and west sides. The area was partially cleared at one time, but much of it has since become overgrown with willows and poplars.

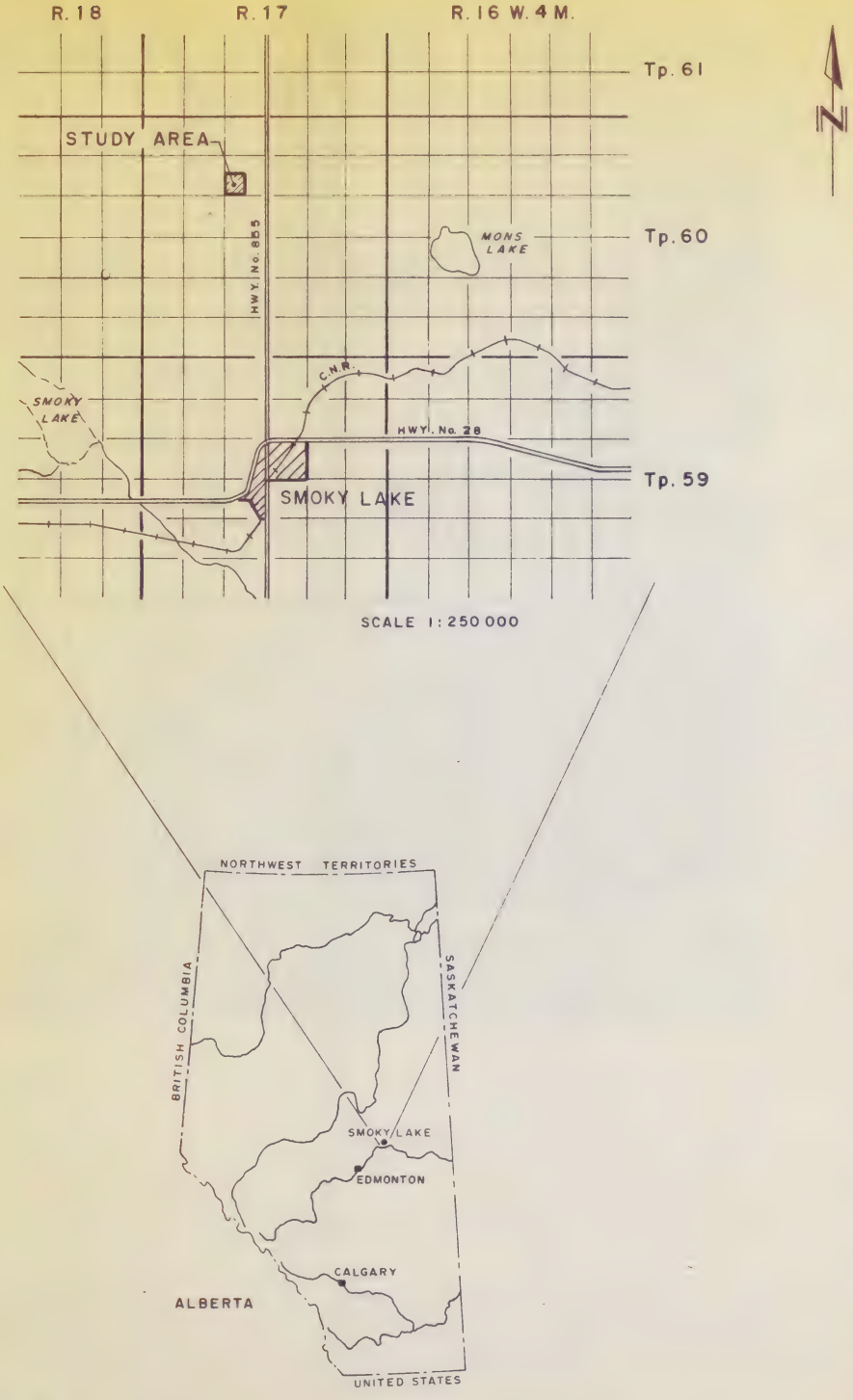
The Groundwater Protection Branch of the Earth Sciences Division, Alberta Environment completed preliminary site drilling in January, 1987 and a preliminary report was released on February 3, 1987. Following review by the Smoky Lake Regional Landfill Authority, cut lines were cleared for access and a detailed hydrogeological site investigation commenced on March 30, 1987. Test drilling was carried out with a truck-mounted Mobile B-61 drill equipped with 108 mm (O.D.) continuous flight augers.

Access within the site is available along an old trail which zig-zags northeast from the abandoned farmstead in the southwest corner of the site, and connects all of the clearings and cutlines. There are two occupied residences immediately adjacent to the site, one in NE 20 and the other in SW 33-60-17-W4. The required 450 m setback from the residence in NE 20 will restrict landfilling in approximately 12 ha (29 acres) of the proposed site (Figure 2).

TOPOGRAPHY AND DRAINAGE

The site has a gently rolling topography with about 12 m of relief. The topography rises to the east from the seasonally wet area along the west side of the property (Figure 3). The general slope of the area is to the west.

The regional drainage network is southwest toward White Earth Creek located about three kilometers away. Surface water drainage within the site is predominantly toward the depressional area along the west side which has no outflow. Surface water that does leave the property appears to flow southwest to a large intermittent lake in SW 20-60-17-W4 and then into White Earth Creek.



Alberta ENVIRONMENT EARTH SCIENCES DIVISION		PROPOSED REGIONAL LANDFILL - SMOKY LAKE	
		LOCATION PLAN	
SUBMITTED DATE	DESIGNED H.O. CHECKED R. RIPPON		
APPROVED DATE	DRAWN H.O. CHECKED	SCALE ——	SHEET OF
		DATE 1987 JUNE	FIGURE No. 1

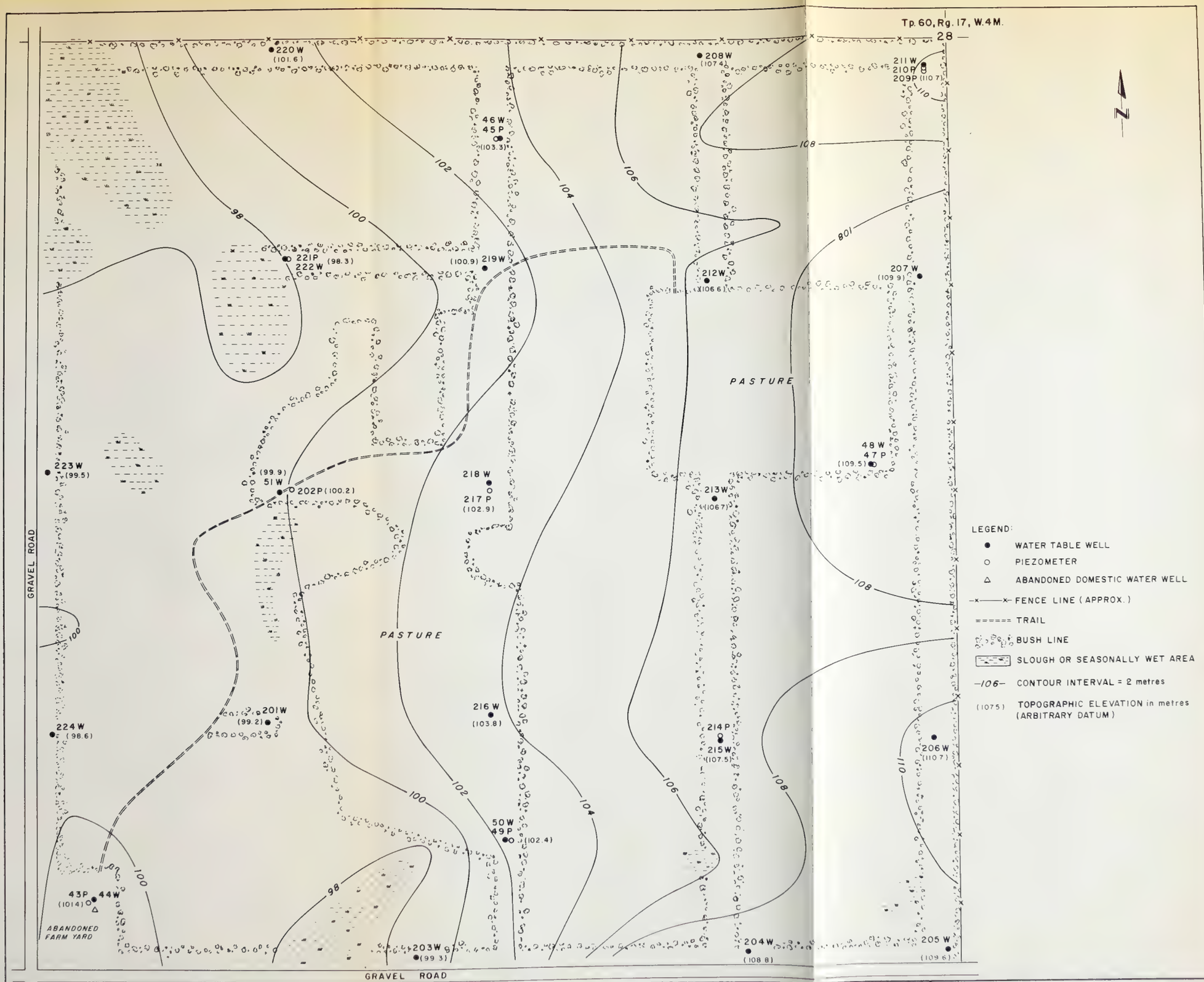
SCALE 1:10000

LEGEND:

□ RESIDENCE

RADIUS FROM RESIDENCE 450 m (1476 ft)

Alberta ENVIRONMENT EARTH SCIENCES DIVISION		PROPOSED REGIONAL LANDFILL - SMOKY LAKE	
		STUDY AREA PLAN	
SUBMITTED DATE	DESIGNED H.O. CHECKED R. RIPPON		
APPROVED DATE	DRAWN H.O. CHECKED	SCALE —— DATE 1987 JUNE	SHEET OF FIGURE No. 2



Alberta ENVIRONMENT

SUBMITTED	DESIGNED R. JACKSON
DATE	CHECKED R. RIPPON
APPROVED	DRAWN N.D.
DATE	CHECKED

PROPOSED REGIONAL LANDFILL SMOKY LAKE

SURFACE TOPOGRAPHY MAP

SCALE	SHEET OF
DATE 198* JUNE	FIGURE No. 3

GEOLOGY

SURFICIAL GEOLOGY

The uppermost surficial materials within the study area consist of till (Kjearsgaard, 1972) deposited as recessional moraine. Lithologic test holes were drilled at 23 locations within SW 28 to a maximum depth of 25.9 m, and were later completed as water table observation wells or as nests consisting of a piezometer and a water table observation well. Bore hole logs are contained in Appendix A.

The proposed landfill site is underlain by two distinct surficial units. The uppermost unit is a medium plastic clay till with sand lenses. Till samples plot within a narrow range on a textural tri-linear plot and are classified as sandy clay or clay-sand (Appendix B). The till unit increases in thickness from a minimum of 13 m in the northwest corner of the site to in excess of 24 m in the southern portion (Figure 4).

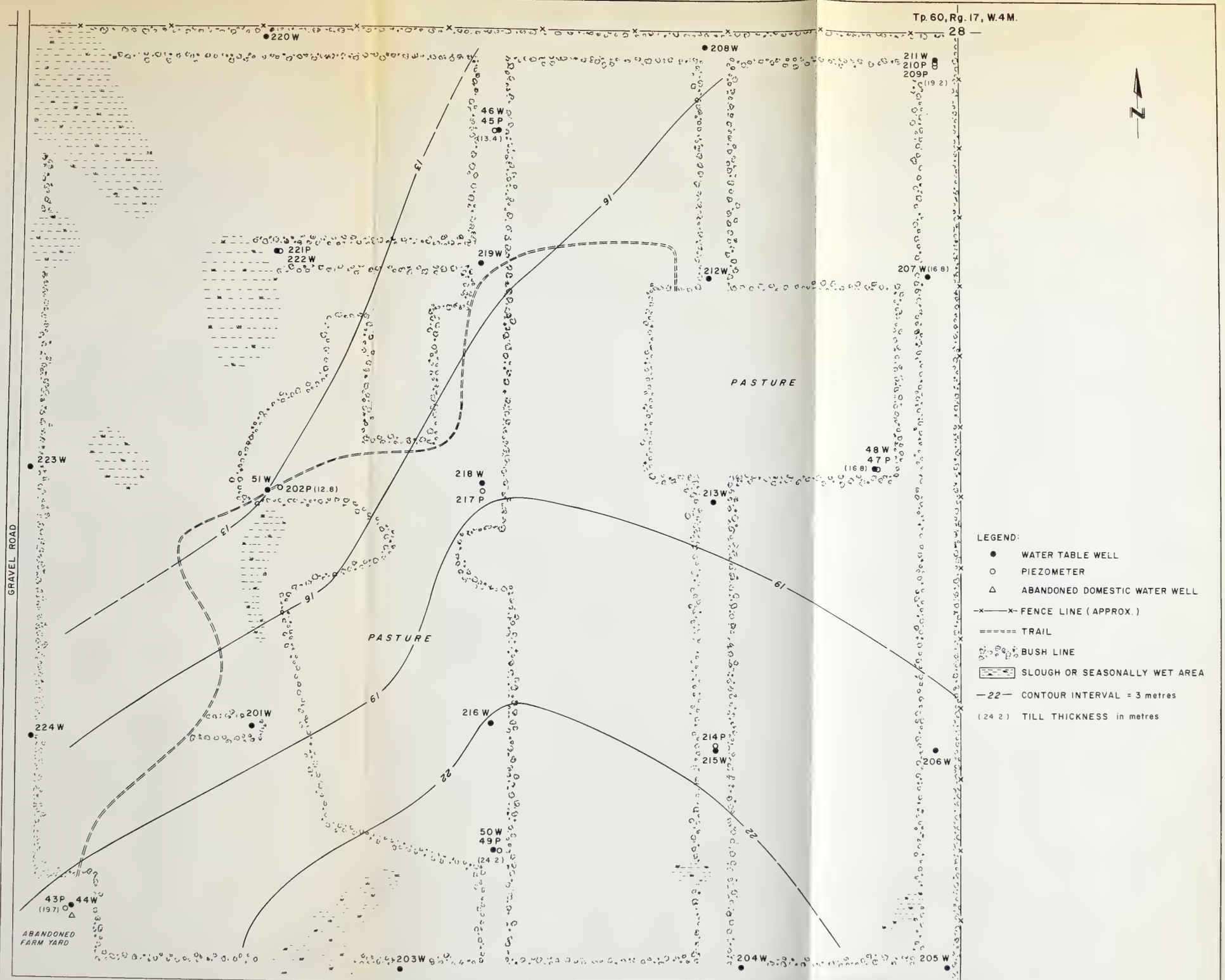
Sand lenses, which had an average thickness of 0.8 m, were intersected at 13 of the 23 test hole locations. Geologic cross-sections (Appendix C) clearly show that the sand lenses are randomly distributed through the till.

A medium to coarse grained sand unit was intersected directly over the bedrock surface in the six deep test holes. The sand unit, possibly preglacial in origin, is quite variable in thickness (0.1 to 4.0 m) and therefore may not underlie the entire site. Test hole 43 P located in the southwest corner of the site appears to have intersected only 0.1 m of sand. Since the sand unit directly underlies the till deposits, the till thickness map (Figure 4) also represents the depth to the top of the sand unit.

BEDROCK GEOLOGY

The Alberta Research Council (Green, 1972) reports that the local bedrock belongs to the Upper Cretaceous Belly River Formation, which is described as:

> "grey to greenish grey, thick-bedded, feldspathic sandstone; grey clayey siltstone, grey and green mudstone; concretionary ironstone beds; nonmarine".



Alberta ENVIRONMENT

SUBMITTED	DESIGNED R JACKSON	PROPOSED REGIONAL LANDFILL SMOKY LAKE
DATE	CHECKED R RIPPON	TILL THICKNESS
APPROVED	DRAWN H.O	SCALE — SHEET OF
DATE	CHECKED	DATE 1987 JUNE FIGURE No 3

Bedrock was intersected by four of the deep test holes at depths between 16.8 and 24.3 m below surface. The bedrock surface dips to the southeast and exhibits a relief of at least 8 m across the site (Figure 5).

The property is located on a bedrock high north of the Preglacial Beverly Valley located approximately 20 kilometers to the south. Tributaries to the Beverly Valley are southwest and northeast of the property (Carlson, 1977).

HYDROGEOLOGY

REGIONAL GROUNDWATER SYSTEM

According to the Alberta Research Council (ARC) (Borneuf, 1973) the proposed landfill site is located in a groundwater recharge area. The direction of regional groundwater flow is southwest toward the North Saskatchewan River, which is adjacent to and roughly parallels the Preglacial Beverly Valley.

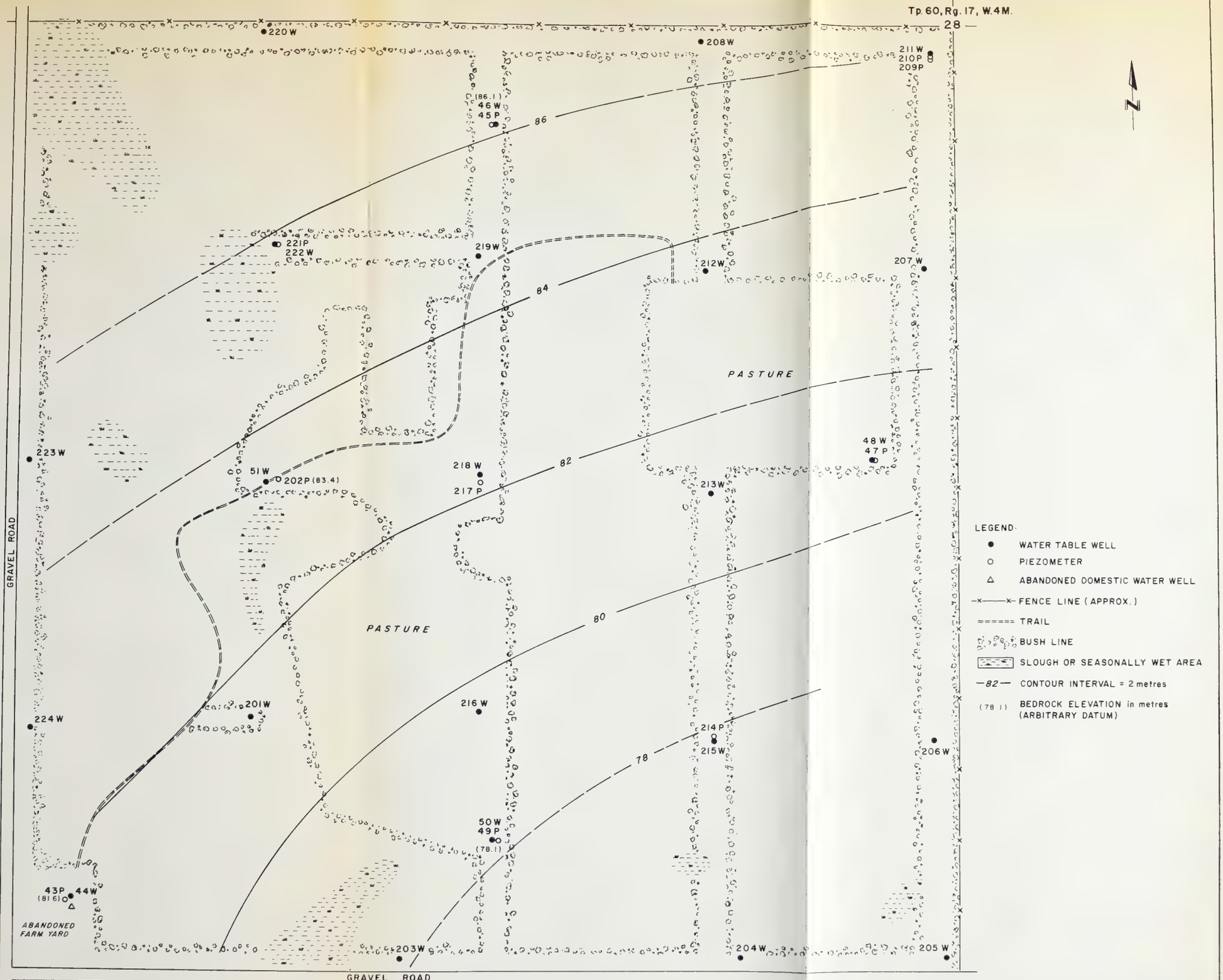
The ARC reports that twenty-year safe yields (Q_{20A}) from aquifers in either the overburden or the Belly River Formation are expected to range from 0.4 L/s to 2.0 L/s. The predominant aquifers utilized locally are sand deposits within the till and either sandstone or shale within the bedrock.

Table 1 summarizes the water well drillers reports on file at the Groundwater Information Service of Alberta Environment in the immediate vicinity of the proposed landfill site.

TABLE 1. SUMMARY OF WATER WELL DRILLER'S REPORTS

WELL LOCATION	OWNER	DEPTH(M)	COMPLETION INTERVAL(M) & AQUIFER	
NW 19-60-17-W4	Not Known	54.8	36.6 - 51.2	SS & SH
NW 20	Kovacs	12.2	9.4 - 11.0	SD
SW 21	Jusypink	36.6	21.3 - 22.8	SD
SW 21	Jusypink	35.0	32.3 - 35.0	SH
SW 21	Jusypink	19.8	-	-
NW 22	Pruskd	20.1	-	-
NW 27	Trachkowsky	30.5	21.3 - 27.4	SD
NW 28	Borchuk	58	53.3 - 57.9	SS, SH
NW 28	Borchuk	18.6	-	-
SW 28	Eisen	15.2	(not in use)	

SS - sandstone SH - shale SD - sand



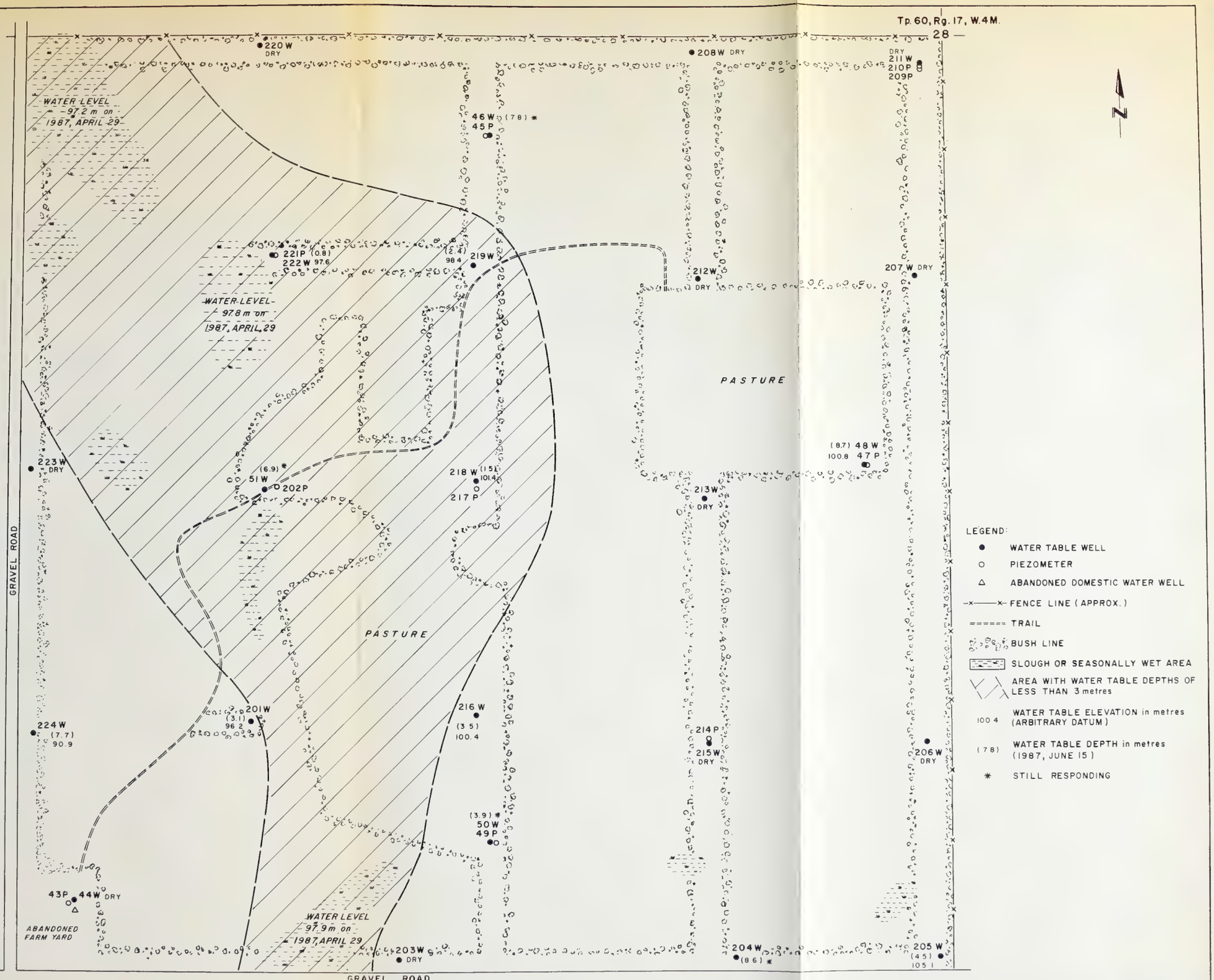
Alberta ENVIRONMENT		PROPOSED REGIONAL LANDFILL - SMOKY LAKE
SUBMITTED Reed Jaeen	DESIGNED R JACKSON	BEDROCK TOPOGRAPHY
DATE 1987 01 22	CHECKED R RIPPON	
APPROVED Colin Chandler	DRAWN N.D	SCALE — SHEET OF
DATE 1987 01 22	CHECKED	DATE 1987 JUNE FIGURE No 5

The wells vary in depth from 12.2 to 58 m and are evenly distributed between surficial sand and bedrock aquifers. The nearest wells are just north of the property in LSD 13 of NW 28-60-17-W4 (Borchuk). The deepest of the two wells is completed in a bedrock aquifer zone between 53.3 and 57.9 m below surface. There is only a chemical water analysis for the shallow 18.6 m deep well, which is probably completed in surficial sands. Other wells in the vicinity all appear to be completed in aquifers at depths in excess of 15 m. There is no record of a well at the residence in LSD 16 of NE 20-60-17-W4, however, the adjacent land owner Mr. Jusypink reports there is an old dug well at the residence reportedly 20 m in depth.

SHALLOW GROUNDWATER SYSTEM

A total of 33 observation wells were constructed at 23 locations within the proposed landfill site (Figure 5 and Appendix A). Twenty three were constructed as water table observation wells and ten as piezometers. Each piezometer was installed in conjunction with a water table well as a "nest", and with an additional piezometer in one case. The "nests", with the piezometers installed at various depths, were used to measure the hydraulic potential of the groundwater flow system at specific points.

Following eleven weeks of monitoring, the water levels in eight water table wells had stabilized and four were still responding (Appendix D). The remaining eleven water table wells, completed at depths between 5.7 and 9.0 m below surface, were dry. The majority of the stabilized water table wells are on the west side of the property, within and adjacent to the numerous seasonally wet areas. Based on the stabilized water table levels, an area of approximately 22 ha (54 ac) has been identified as having a water table depth of less than 3 m (Figure 6). The dry observation wells are concentrated in the east half of the property, which is higher and better drained. A water table contour map could not be constructed due to the variable water table levels and the number of dry wells . Instead, a water table depth and elevation map (Figure 6) was prepared. Based on this map and the surface topography map (Figure 3), it can be inferred that the water table slopes to the west.



Alberta ENVIRONMENT		PROPOSED REGIONAL LANDFILL - SMOKY LAKE
SUBMITTED Reed Hart	DESIGNED R JACKSON	WATER TABLE DEPTH AND ELEVATION
DATE 1991 01 17	CHECKED R RIPPON	
APPROVED David Franklin	DRAWN N.Q	SCALE —— SHEET OF
DATE 1991 01 22	CHECKED	DATE 1987 JUNE FIGURE No 5

Water levels in five of the ten piezometers have stabilized, one is responding slowly and four are dry (Appendix D). Four of the piezometers were completed in till, four in the sand directly overlying the bedrock and two in the upper shale bedrock to facilitate hydraulic conductivity testing.

An evaluation of the water table levels, piezometer levels and the dry observation wells indicates that the groundwater observed in the upper till deposit is in a perched condition. Nest 47P/48W is an example of a stabilized water table well associated with a deeper dry piezometer, indicating a perched water table.

The sand unit overlying bedrock is not considered a major aquifer. The unit is either thin, as evidenced by test holes 43 P and 49 P which only encountered 0.1 m of sand; or not fully saturated, as indicated by water table conditions present at piezometers 45 P and 202 P. Water levels measured at 45 P and 202 P indicate flow within the sand unit has a slight southward gradient.

The horizontal hydraulic conductivity (k) of the various geological materials was determined using a microcomputer program for interpreting time-lag permeability tests (Thompson, 1987) (Appendix E) and found to range from a high of 1×10^{-4} cm/s for a sand lens in the till to a low of 3×10^{-9} cm/s in the till. More specifically, the k values for the sand lenses ranged from 1×10^{-4} cm/s to 5×10^{-7} cm/s, while the till k values ranged from 7×10^{-6} cm/s to 3×10^{-9} cm/s. A single k value of 2×10^{-6} cm/s was calculated for shale.

To determine the velocity of groundwater three parameters must be known; the hydraulic conductivity of the geologic material, the hydraulic gradient and the porosity of the medium (Freeze and Cherry, 1979). The variable nature of these parameters will produce variations in groundwater velocity beneath the property. In order to determine a possible range in groundwater velocity within the till deposits, combinations of hydraulic conductivity and gradient have been used. Groundwater velocity within the sand lenses was not calculated as the lenses are surrounded by a till matrix which will ultimately control the velocity of groundwater flow. The hydraulic gradient, as measured between water table wells 219 W and 222 W, and 216 W and 201 W, varies between 5×10^{-3} and 2×10^{-2}. As previously stated, the hydraulic conductivity of the till ranges from 3×10^{-9} cm/s to 7×10^{-6} cm/s. Assembling the conductivity and gradient values into various combinations, assuming a porosity of 20% (Terzaghi and Peck, 1948) the range of possible velocity values are summarized in Table 2.

TABLE 2. RANGE OF GROUNDWATER VELOCITY

Gradient	2×10^{-2}	5×10^{-3}
Hydraulic Conductivity (cm/s)	Maximum velocity	
7×10^{-6}	7×10^{-7} cm/s	2×10^{-7} cm/s
3×10^{-9}	3×10^{-10} cm/s	8×10^{-11} cm/s
		Minimum velocity

From the Table, the velocity of groundwater flow is estimated to be in the range of 8×10^{-11} cm/s to 7×10^{-7} cm/s, which, when converted to more recognizable units, is in the range of less than 1 cm/year to 22 cm/year.

SUMMARY AND CONCLUSIONS

The proposed landfill site has a gently rolling topography with about 12 m of relief. A large seasonally wet area lies along the west side, but the site is otherwise well drained. The regional drainage network is southwest toward White Earth Creek.

The study area is underlain by thick till deposited as recessional moraine. The till unit increases in thickness from a minimum of 13 m in the northwest corner of the site to in excess of 24 m in the southern portion. A medium to coarse grained sand, which varies in thickness from 0.1 to 4.0 m, overlies the bedrock surface throughout much of the site. Bedrock was intersected by four of the deep test holes at depths between 16.8 and 24.3 m. Bedrock aquifers in the area are capable of twenty year yields (Q_{20A}) ranging from 0.4 L/s to 2.0 L/s. Sand deposits within the till or bedrock shale and sandstone, are predominant aquifers in the area. Most wells in the vicinity of the proposed landfill are completed at depths in excess of 15 m.

There are two separate water tables within the shallow groundwater regime - a perched water table in the till and an unconfined water table in the underlying sand unit. The sand zone is not considered a major aquifer since testing has shown it is thin, possibly discontinuous and not fully saturated.

Hydraulic conductivity values obtained from piezometers within the till ranged from 3×10^{-9} cm/s to 7×10^{-6} cm/s. As a result, the estimated groundwater velocity within the till varies from less than 1 cm/year to 22 cm/year.

The proposed site at SW 28-60-17-W4 is considered to be hydrogeologically suitable for development of a regional landfill subject to the following conditions:

1. A 7.4 ha (18 ac) area which lies within the south west corner of the property is restricted from development due to the required 450 m set back from the residence in LSD 16 of NE 20-60-17-W4.

2. Landfilling should not take place within undrained depressions nor should surface water be allowed to collect in the trenches.

3. Trench depth should be restricted to above the water table to avoid intersecting a saturated sand lens. Based on the water table depth and elevation map (Figure 6) there is an area of at least 37 ha (90 ac) which is suitable for landfill development with trench depths of at least 3 m.

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Terzaghi, K. and Peck, R.B.; 1948: Soil Mechanics in Engineering Practice; John Wiley Inc., New York, N.Y.; 729 pp.

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APPENDIX A

TEST HOLE LOGS

GROUNDWATER PROTECTION BRANCH DRILL HOLE LOG

Land Location SW Sec. 28 Tp. 60 R. 17 W 4

Date Jan 28 & 29, Mar 30 & 31, Apr 1, 1987 Supervisor RJ

Project Proposed Regional Landfill - Smoky Lake

Test Hole 87-43 to 87-51 and 87-201 to 87-224 inclusive.

Test Hole 43(P)

DEPTH (m)	DEPOSIT	DESCRIPTION	M.C.*
0.0 - 1.2	clay till	brown, sandy, frequent sand partings, stiff, medium plastic	sm
1.2 - 3.0	clay till	a/a, grey-brown, more uniform texture	sm
3.0 - 4.6	clay till	a/a, darker	sm
4.6 - 6.4	clay till	a/a lighter	sm
6.4 - 12.2	clay till	a/a	sm-m
12.2 - 13.7	clay till	a/a, darker	m
13.7 - 19.7	clay till	a/a, grey	m
19.7 - 19.8	sand	grey, coarse, coal fragments	s
19.8 - 21.3	shale	brown and dark brown, very stiff, high plastic	sm

Water at 19.8 m at completion
Completion: 50 mm PVC piezometer
screened interval: 20.3 - 20.9 m (0.65m)

TH 44(W)

0.0 - 9.1 same as 43(P)

Dry at completion
Completed: 50 mm PVC water table well
slotted interval: 5.7 - 8.7 m

*M.C. (Moisture Content): d(dry); sm(slightly moist); m(moist); vm(very moist); s(saturated)

#123

DEPTH (m)	DEPOSIT	DESCRIPTION	M.C.*
TH 45(P)			
0.0 - 0.5	sand	brown, fine, silty	d
0.5 - 1.5	clay till	brown, very sandy, sand partings, stiff	sm
1.5 - 6.1	clay till	grey-brown, uniform texture, medium plastic	sm
6.1 - 9.1	clay till	a/a	sm-m
9.1 - 12.2	clay till	a/a, darker	m
12.2 - 13.4	clay till	a/a, grey	m
13.4 - 16.2	sand	brown, fine-medium	d-sm
16.2 - 16.8	sand	a/a, thin coarse layers	s
16.8 - 17.2	silt	brown & grey, sandy-clayey	s
17.2 - 17.4	shale	grey, stiff, sandy	sm
17.4 - 18.3	shale	a/a, olive-grey	sm-m

Water and slough at 15.2 m at completion
Completed: 50 mm PVC piezometer
screened interval: 16.0 - 16.4 m (0.41m)

TH 46(W)

0.0 - 9.1 same as TH 45(P)

Dry at completion
Completed: 50 mm PVC water table well
slotted interval: 5.8 - 8.8 m

TH 47(P)			
0.0 - 0.1	topsoil		
0.1 - 0.3	sand	brown, fine-medium	d
0.3 - 1.2	clay till	brown, sandy, sand seams stiff	d-sm
1.2 - 4.9	clay till	grey-brown, sandy, uniform texture, stiff, medium plastic	sm

(continued)

*M.C. (Moisture Content): d(dry); sm(slightly moist); m(moist); vm(very moist); s(saturated)

#123

DEPTH (m)	DEPOSIT	DESCRIPTION	M.C.*
TH 47(P) (Continued)			
4.9 - 12.2	clay till	a/a, a few cobbles	sm-m
12.2 - 13.7	clay till	a/a, darker	m
13.7 - 16.8	clay till	a/a, grey	m
16.8 - 17.7	sand	brown, medium-coarse, very dense	d-sm
17.7 - 17.8	sand?/ sandstone?	powdered sample, extremely hard, refusal at 17.8 m	d?

Dry at completion
Completed: 50 mm PVC piezometer
screened interval: 17.0 - 17.4 m (0.43m)

TH 48(W)

0.0 - 9.1 same as TH 47 (P)

Dry at completion
Completed: 50 mm PVC water table well
slotted interval: 5.8 - 8.8 m

TH 49(P)

0.0 - 1.2	clay till	brown, sandy, sand partings, stiff, medium plastic	sm
1.2 - 3.7	clay till	a/a, uniform texture	sm
3.7 - 7.6	clay till	a/a, darker	sm-m
7.6 - 20.1	clay till	a/a, grey	m
20.1 - 22.9	clay till	a/a, very stiff, hard seams at 20.1-20.4 m & 21.3-21.9 m	m
22.9 - 24.2	clay till	a/a, dark grey	m
24.2 - 24.3	sand	grey, fine, coal fragments	s
24.3 - 25.9	shale	dark brown, carboniferous, thin seams of grey bentonitic sandstone, hard	sm

Trace of water at completion
Completed: 50 mm PVC piezometer
screened interval: 24.9 - 25.3 m (0.43 m)

*M.C. (Moisture Content): d(dry); sm(slightly moist); m(moist); vm(very moist); s(saturated)

#123

DEPTH (m)	DEPOSIT	DESCRIPTION	M.C.*
TH 50(W)			
0.0 - 9.1	same as TH 49(P)		
Dry at completion Completed: 50 mm PVC water table well slotted interval: 5.7 - 8.7 m			
TH 51(W)			
0.0 - 1.4	till	brown, very sandy, numerous sand seams, stiff	d-sm
1.4 - 2.1	clay till	grey-brown, sandy, stiff, medium plastic	sm
2.1 - 6.1	clay till	a/a	sm-m
6.1 - 7.6	clay till	a/a, darker	m
Dry at completion Completed: 50 mm PVC water table well slotted interval: 4.3 - 7.3 m			
TH 201 (W)			
0.0 - 0.2	topsoil		
0.2 - 1.2	clay till	grey-brown, sandy, stiff, medium plastic	sm
1.2 - 1.4	sand	brown, medium - coarse grained	d-sm
1.4 - 3.0	clay till	grey-brown, sandy, stiff, medium plastic	sm
3.0 - 7.6	clay till	a/a, darker	sm-m
Dry at completion Completed: 50 mm PVC water table well slotted interval: 4.4 - 7.4 m			
TH 202 P			
0.0 - 7.6	same as TH 51 (W)		
7.6 - 11.2	clay till	grey-brown, sandy, stiff, medium plastic	sm-m

(continued)

*M.C. (Moisture Content): d(dry); sm(slightly moist); m(moist); vm(very moist); s(saturated)

#123

DEPTH (m)	DEPOSIT	DESCRIPTION	M.C.*
TH 202 P (continued)			
11.2 - 12.8	clay till	a/a, grey	m
12.8 - 13.7	sand	brown, coarse	sm-m
13.7 - 16.8	sand	a/a	s
16.8 - 18.9	shale	grey, sandy, till lenses, firm	m
18.9 - 19.8	shale	grey, very stiff-hard	sm

Water and slough at 13.7 m at completion
Completed: 50 mm PVC piezometer
screened interval: 13.3 - 14.0 m (0.68m)

TH 203 (W)			
0.0 - 0.2	topsoil		
0.2 - 1.5	clay	brown & grey, stiff, medium-high plastic	sm
1.5 - 6.4	clay till	grey-brown, sandy, stiff, medium plastic	sm
6.4 - 6.7	sand	brown, medium grained	d
6.7 - 7.3	clay till	a/a	sm
7.3 - 9.1	clay till	a/a, darker	sm-m

Dry at completion
Completed: 50 mm PVC water table well
slotted interval: 5.8 - 8.8 m

TH 204 (W)			
0.0 - 0.2	topsoil		
0.2 - 1.5	clay till	grey-brown, sandy, numerous thin sand seams	d-sm
1.5 - 6.7	clay till	grey-brown, sandy, stiff, medium plastic	sm
6.7 - 7.0	sand	brown, medium grained	m

(continued)

*M.C. (Moisture Content): d(dry); sm(slightly moist); m(moist); vm(very moist); s(saturated)

#123

DEPTH (m)	DEPOSIT	DESCRIPTION	M.C.*
TH 204 (W) (continued)			
7.0 - 7.9	till	brown, very sandy, frequent cobbles, hard	sm
7.9 - 9.1	clay till	dark grey-brown, sandy stiff, medium plastic	sm-m

Dry at completion
Completed: 50 mm PVC water table well
slotted interval: 5.8 - 8.8 m

TH 205 (W)			
0.0 - 0.2	topsoil		
0.2 - 3.0	clay till	grey-brown, sandy, stiff, medium plastic	sm
3.0 - 6.1	clay till	a/a	sm-m
6.1 - 7.9	clay till	a/a, grey	m
7.9 - 9.8	sand	brown, medium grained	s
9.8 - 10.7	clay till	a/a, grey	m

Water at 7.6 m at completion
Completed: 50 mm PVC water table well
slotted interval 7.5 - 10.5 m

TH 206 (W)			
0.0 - 0.2	topsoil		
0.2 - 2.1	clay till	grey-brown, sandy, white deposits, stiff, medium plastic	sm
2.1 - 4.9	sand	brown, fine-medium grained, till lenses	d-sm
4.9 - 5.5	till	dark grey-brown, very sandy, a few sand seams (vm)	m
5.5 - 7.6	clay till	grey, very sandy, a few thin sand seams (vm?)	m-vm

Dry at completion
Completed: 50 mm PVC water table well
slotted interval: 4.4 - 7.4 m

*M.C. (Moisture Content): d(dry); sm(slightly moist); m(moist); vm(very moist); s(saturated)

#123

DEPTH (m)	DEPOSIT	DESCRIPTION	M.C.*
TH 207 (W)			
0.0 - 0.2	topsoil		
0.2 - 7.0	clay till	grey-brown, sandy, stiff, medium plastic	sm
7.0 - 7.6	clay till	a/a, grey	sm-m

Dry at completion
Completed: 50 mm PVC water table well
slotted interval: 4.3 - 7.3

TH 208 (W)			
0.0 - 0.2	topsoil		
0.2 - 2.1	sand	brown, fine grained, silty	d
2.1 - 2.7	clay till	grey-brown, sandy, stiff, medium plastic	sm
2.7 - 3.3	sand	brown, fine grained, silty	d
3.3 - 4.3	clay till	dark grey-brown, sandy, stiff, medium plastic	sm-m
4.3 - 6.1	clay till	a/a, grey	m

Dry at completion
Completed: 50 mm PVC water table well
slotted interval: 2.7 - 5.7 m

TH 209 (P)			
0.0 - 0.2	topsoil		
0.2 - 1.2	clay till	grey-brown, sandy, stiff, medium plastic	sm
1.2 - 3.3	till	brown, numerous thin sand seams, very stiff, low plastic	d
3.3 - 5.2	till	a/a, stoney, hard	d
5.2 - 7.3	clay till	grey-brown, sandy, stiff, medium plastic	sm
7.3 - 7.6	sand	brown, fine grained, silty	d-sm
7.6 - 8.2	clay till	a/a, darker	sm-m

(continued)

*M.C. (Moisture Content): d(dry); sm(slightly moist); m(moist); vm(very moist); s(saturated)

#123

DEPTH (m)	DEPOSIT	DESCRIPTION	M.C.*
TH 209 (P) (continued)			
8.2 - 12.8	clay till	a/a, grey	m
12.8 - 17.7	clay till	a/a, grey-brown	sm-m
17.7 - 19.2	clay till	a/a, sandier	sm
19.2 - 21.3	sand/ (siltstone?)	brown, extremely hard, powdered sample	d?

Cry at completion
Completed: 50 mm PVC piezometer
screened interval: 20.2 - 20.6 m (0.37m)

TH 210 (P)

0.0 - 7.6	same as TH 209 (P)		
7.6 - 8.0	sand	grey, fine, very silty	vm-s
8.0 - 10.7	clay till	dark grey-brown, sandy, stiff, medium plastic	sm-m

Dry at completion
Completed: 50 mm PVC piezometer
screened interval 9.9 - 10.4 m (0.50 m)

TH 211 (W)

0.0 - 6.7	same as TH 209 (P)		
6.7 - 7.9	sand	brown, fine, silty	d
7.9 - 9.1	clay till	dark grey-brown, sandy, stiff, medium plastic	sm-m

Dry at completion
Completed: 50 mm PVC piezometer
slotted interval: 5.8 - 8.8 m

TH 212 (W)

0.0 - 0.2	topsoil		
0.2 - 0.6	clay till	grey-brown, sandy, stiff, medium plastic	sm

(continued)

*M.C. (Moisture Content): d(dry); sm(slightly moist); m(moist); vm(very moist); s(saturated)

#123

DEPTH (m)	DEPOSIT	DESCRIPTION	M.C.*
TH 212 (W) (continued)			
0.6 - 0.9	sand	brown medium grained	d
0.9 - 1.5	clay till	grey-brown, sandy, numerous sand seams (d)	sm
1.5 - 3.3	clay till	grey-brown, sandy, a few cobbles, stiff, medium plastic	sm
3.3 - 9.1	clay till	a/a	sm-m

Dry at completion
Completed: 50 mm PVC water table well
slotted interval: 5.9 - 8.9 m

TH 213 (W)			
0.0 - 0.2	topsoil		
0.2 - 1.5	clay till	grey-brown, sandy, a few thin silty sand seams, stiff, medium plastic	d-sm
1.5 - 9.1	clay till	a/a, no sand seams	sm

Dry at completion
Completed: 50 mm PVC water table well
slotted interval: 5.7 - 8.7 m

TH 214 (P)			
0.0 - 3.2	clay till	grey-brown, sandy, stiff, medium plastic	sm
3.2 - 4.7	sand	brown, fine-medium grained, very dense	d
4.7 - 7.0	clay till	a/a	sm
7.0 - 7.9	sand	brown, fine-medium	d
7.9 - 9.4	till	grey-brown, very sandy, hard, low plastic	sm
9.4 - 12.8	clay till	grey-brown, sandy, very stiff, medium plastic	sm-m

(continued

*M.C. (Moisture Content): d(dry); sm(slightly moist); m(moist); vm(very moist); s(saturated)

#123

DEPTH (m)	DEPOSIT	DESCRIPTION	M.C.*
TH 214 (P) (continued)			
12.8 - 13.7	clay till	a/a, darker	m

Dry at completion
Completed: 50 mm PVC piezometer
screened interval: 13.0 - 13.5 m

TH 215 (W)			
0.0 - 6.7	clay till	grey-brown, sandy, stiff, medium plastic	sm
6.7 - 8.5	till	brown, very sandy, thin sand lenses (d), hard, low plastic	d-sm
8.5 - 9.1	clay till	dark grey-brown, sandy, stiff, medium plastic	sm-m

Dry at completion
Completed: 50 mm PVC water table well
slotted interval: 5.3 - 8.3 m

TH 216 (W)			
0.0 - 0.2	topsoil		
0.2 - 3.0	clay till	grey-brown, sandy, stiff, medium plastic	sm
3.0 - 7.6	clay till	a/a	sm-m
7.6 - 9.1	clay till	a/a, grey	m

Dry at completion
Completed: 50 mm PVC water table well
slotted interval: 5.9 - 8.9 m

TH 217 (P)			
0.0 - 0.2	topsoil		
0.2 - 1.5	clay till	brown, sandy, extensive white deposits, stiff, medium plastic	sm
1.5 - 5.8	clay till	a/a, grey-brown, no white deposits	sm-m
5.8 - 9.1	clay till	a/a, grey	m

Dry at completion
Completed: 50 mm PVC piezometer
screened interval: 8.4 - 8.8 m
*M.C. (Moisture Content): d(dry); sm(slightly moist); m(moist); vm(very moist); s(saturated)

DEPTH (m)	DEPOSIT	DESCRIPTION	M.C.*

TH 218 (W)

0.0 - 7.6	same as TH 217 (P)		

Dry at completion
Completed: 50 mm PVC water table well
slotted interval: 4.3 - 7.3 m

TH 219 (W)

0.0 - 0.2	topsoil		
0.2 - 0.6	sand	brown, fine, silty	d
0.6 - 2.1	clay till	grey-brown, sandy, stiff, medium plastic	sm
2.1 - 6.1	clay till	a/a, darker	sm-m

Dry at completion
Completed: 50 mm PVC water table well
slotted interval: 2.8 - 5.8 m

TH 220 (W)

0.0 - 0.2	topsoil		
0.2 - 1.5	clay till	grey-brown, a few sand seams (d)	d-sm
1.5 - 6.4	clay till	a/a, no sand seams	sm
6.4 - 9.1	clay till	a/a, sandier, very stiff	sm

Dry at completion
Completed: 50 mm PVC water table well
slotted interval: 6.0 - 9.0 m

TH 221 (P)

0.0 - 0.2	topsoil		
0.2 - 1.2	clay till	grey-brown, sandy white deposits, firm, medium plastic	sm
1.2 - 2.7	clay till	a/a, stiff	sm
2.7 - 4.9	clay till	a/a, darker	m
4.9 - 7.6	clay till	a/a, grey	m

Dry at completion
Completed: 50 mm PVC piezometer
screened interval: 6.9 - 7.3 m (0.38 m)

*M.C. (Moisture Content): d(dry); sm(slightly moist); m(moist); vm(very moist); s(saturated)

DEPTH (m)	DEPOSIT	DESCRIPTION	M.C.*
TH 222 (W)			
0.0 - 4.6	same as TH 221 (P)		

Dry at completion
Completed: 50 mm PVC water table well
slotted interval: 1.3 - 4.3 m

TH 223 (W)			
0.0 - 0.2	topsoil		
0.2 - 0.5	sand	brown, fine, silty	d
0.5 - 1.5	clay till	grey-brown, sandy, a few thin sand seams, stiff, medium plastic	sm
1.5 - 6.4	clay till	a/a, very stiff	sm
6.4 - 8.5	clay till	a/a, darker	sm
8.5 - 9.1	clay till	a/a, grey	sm-m

Dry at completion
Completed: 50 mm PVC water table well
slotted interval: 5.9 - 8.9 m

TH 224 (W)			
0.0 - 0.5	sand	brown, fine, silty	d
0.5 - 1.2	clay till	brown & grey, sandy, mottles, oxides, thin sand seams (d)	sm
1.2 - 6.4	clay till	grey-brown, sandy, stiff, medium plastic	sm
6.4 - 9.1	clay till	a/a, darker	sm-m

Dry at completion
Completed: 50 mm PVC water table well
slotted interval: 6.0 - 9.0 m

*M.C. (Moisture Content): d(dry); sm(slightly moist); m(moist); vm(very moist); s(saturated)

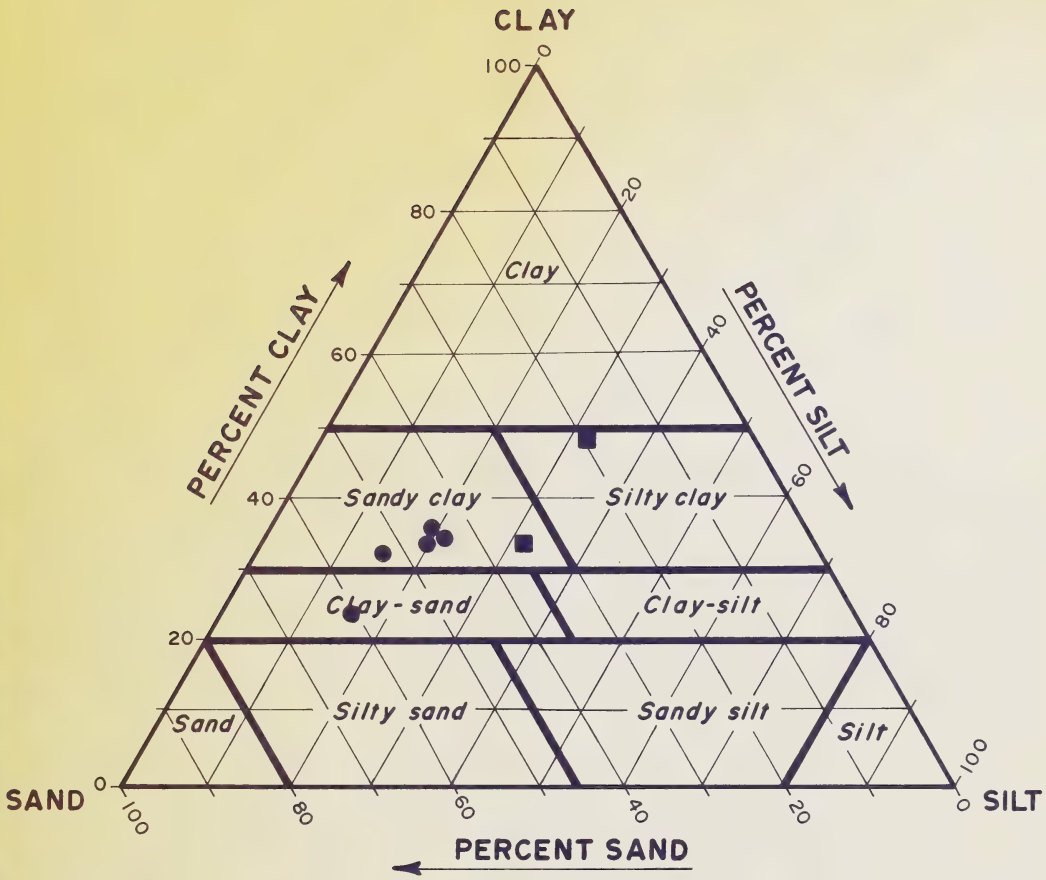
#123

APPENDIX B

TEXTURAL TRI-LINEAR PLOT

SIZE LIMITS

SAND ..... 2.0 TO 0.05 mm
SILT.....0.05 TO 0.005 mm
CLAY.....LESS THAN 0.005 mm



LEGEND:

● GLACIAL TILL

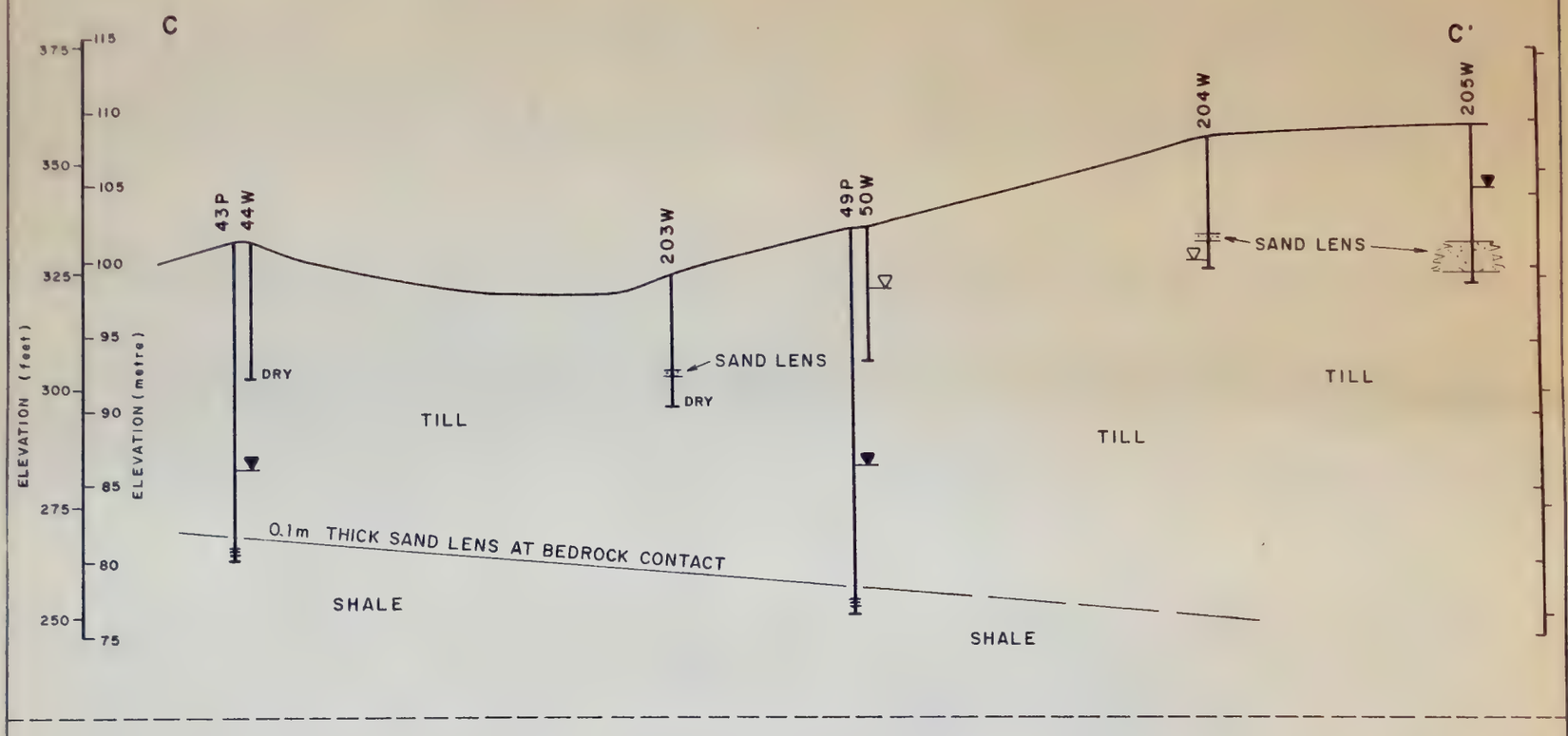
■ SHALE BEDROCK

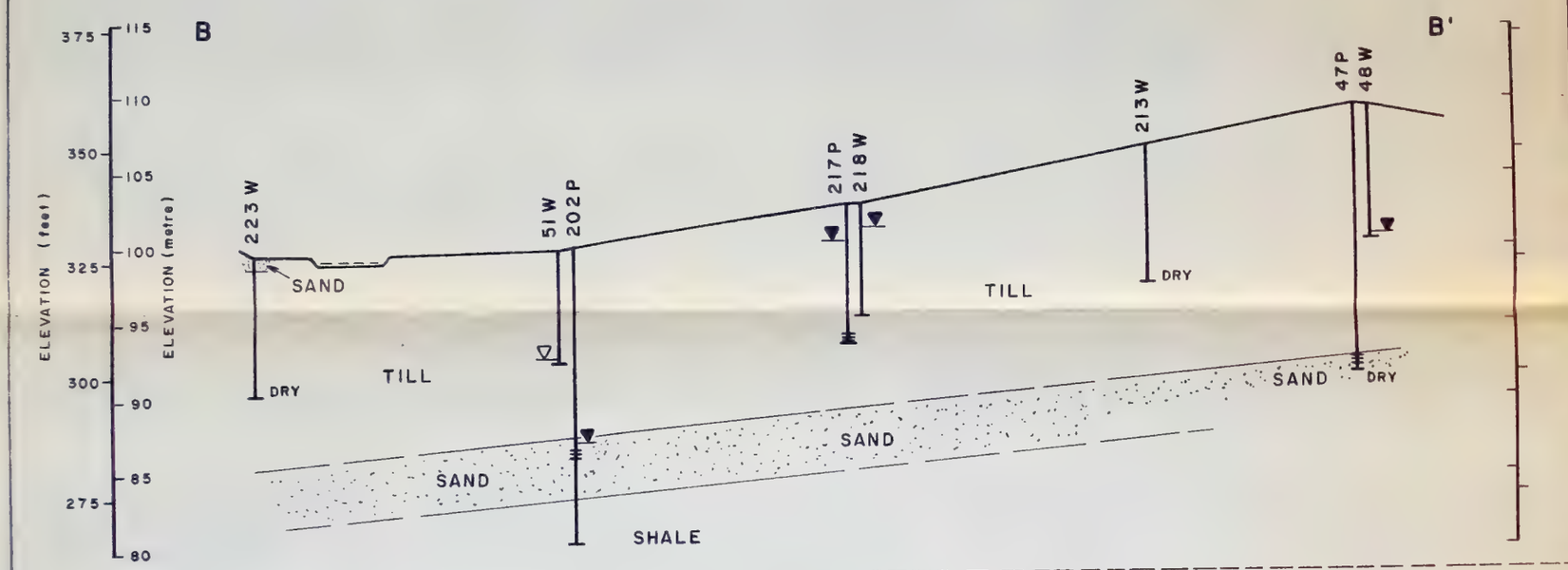
NOTE: ADAPTED FROM U.S. ARMY CORPS OF ENGINEERS

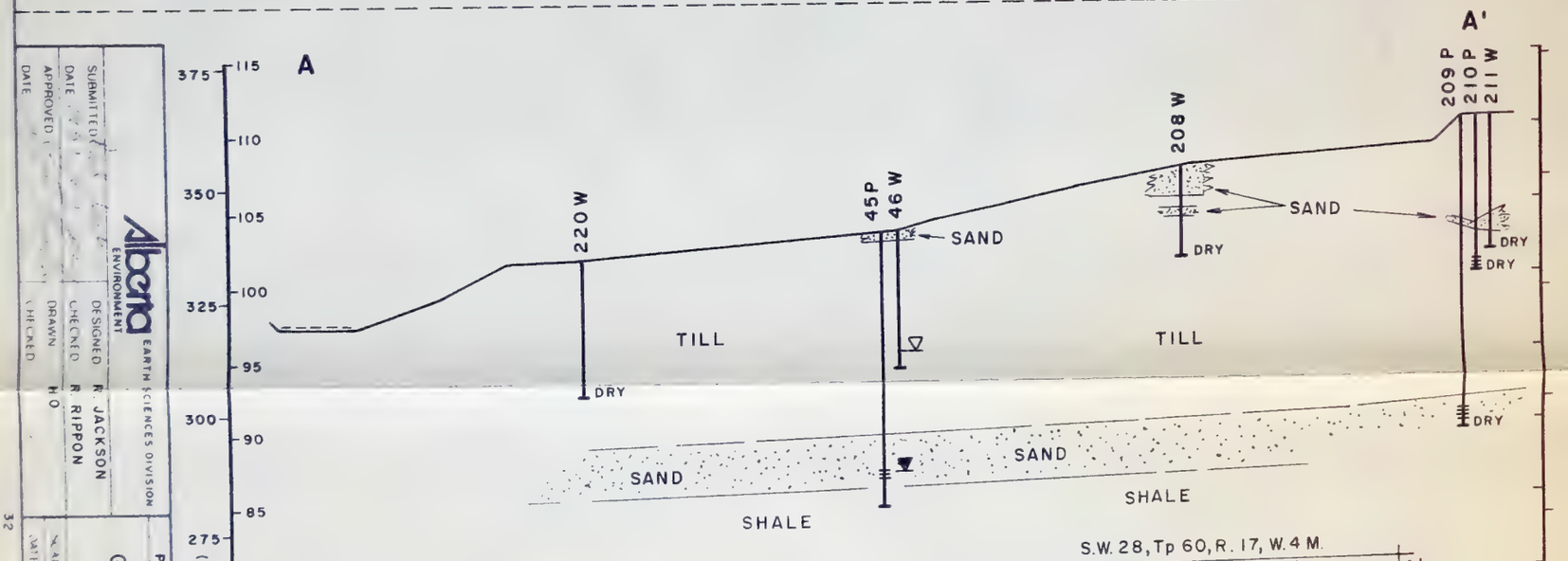
Alberta ENVIRONMENT		PROPOSED REGIONAL LANDFILL-SMOKY LAKE
SUBMITTED	DESIGNED R. JACKSON	TEXTURAL TRI-LINEAR PLOT
DATE	CHECKED R. RIPPON	S. W. Sec. 28 Tp. 60 R. 17 W. 4 M.
APPROVED	DRAWN H.O.	SCALE ——— SHEET OF
DATE	CHECKED	DATE 1987 JUNE FIGURE No. B 1

APPENDIX C

GEOLOGIC CROSS-SECTIONS



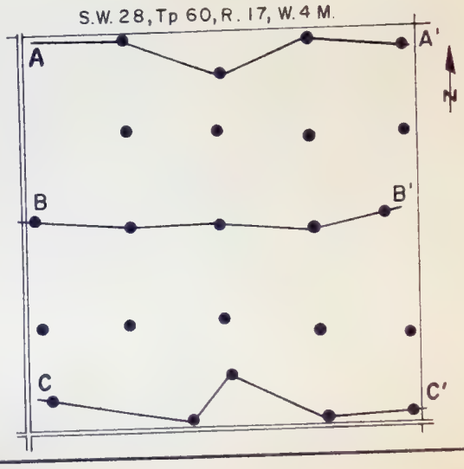




LEGEND:

- WATER TABLE WELL
- PIEZOMETER
- STABILIZED WATER LEVEL (1987,06,15)
- RESPONDING WATER LEVEL (1987,06,15)

HORIZONTAL SCALE
0 50 100 150 200 metre
0 200 400 600 feet



Alberta Environment
EARTH SCIENCES DIVISION

SUBMITTED
DATE
APPROVED
DATE

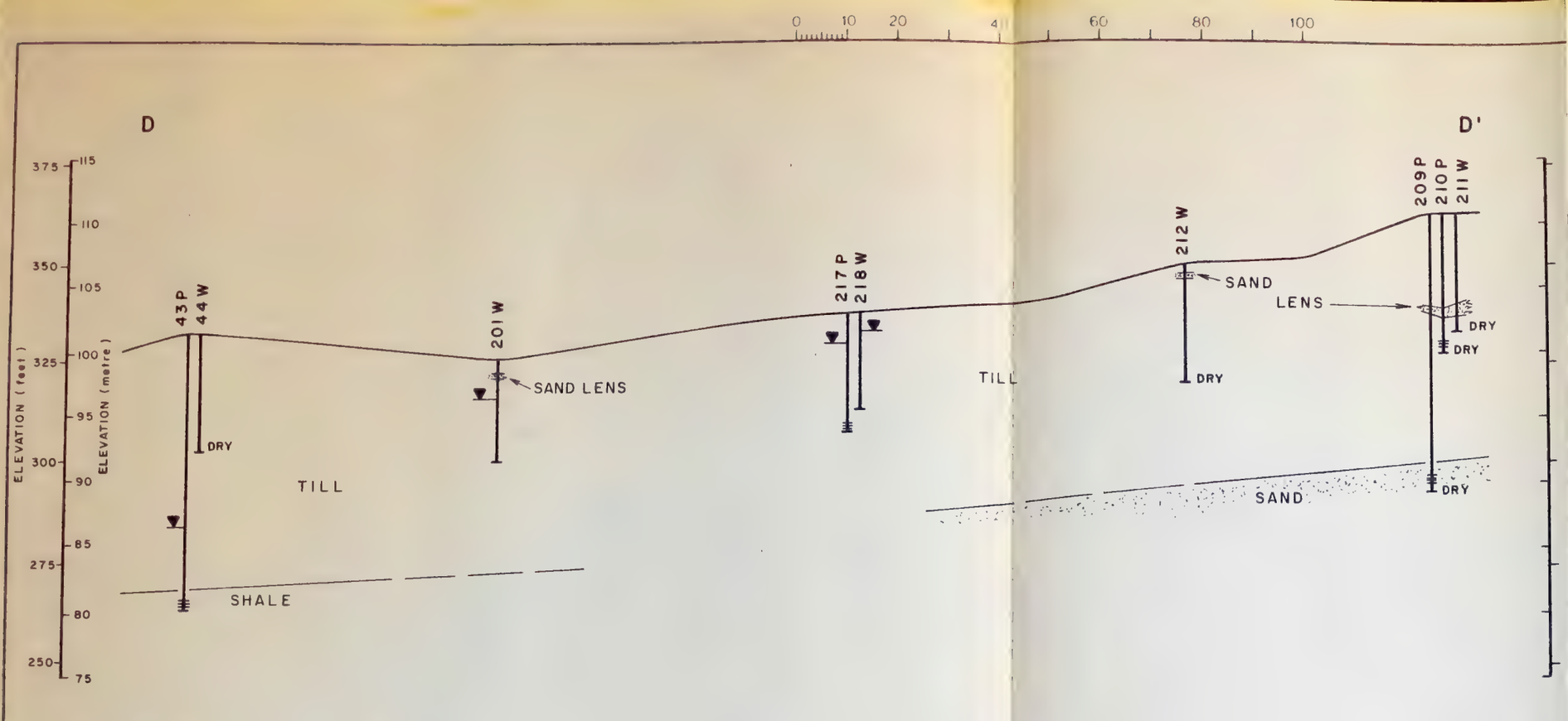
DESIGNED R. JACKSON
CHECKED R. RIPPON
DRAWN H.O.
CHECKED

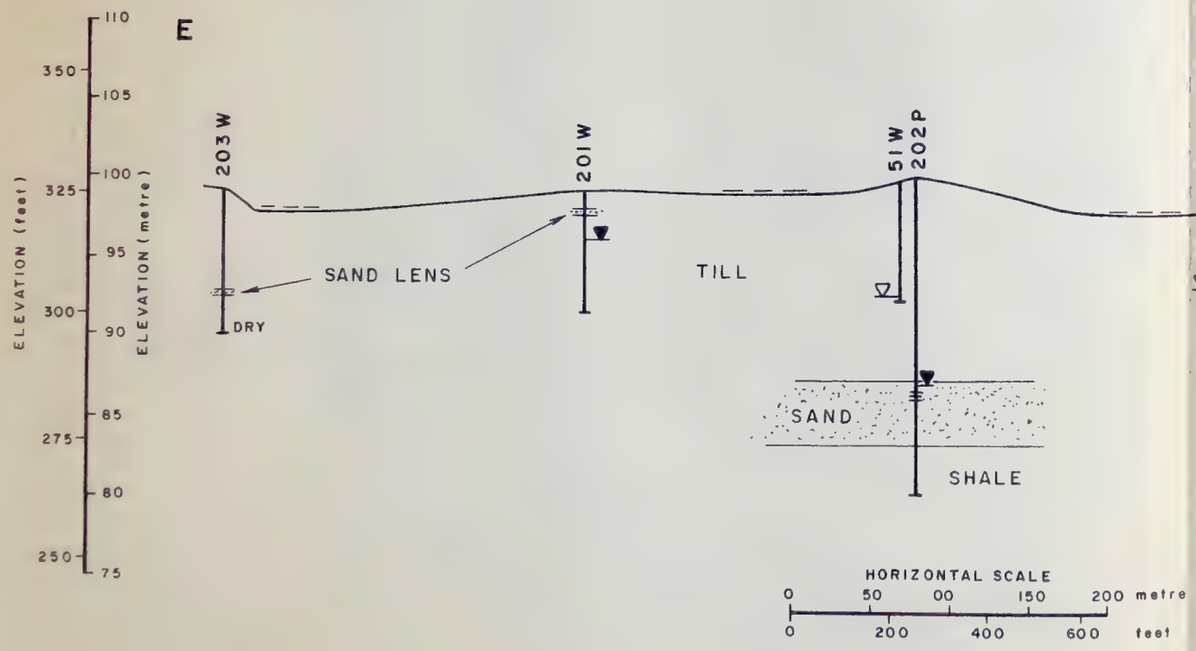
PROPOSED REGIONAL LANDFILL - SMOKY LAKE

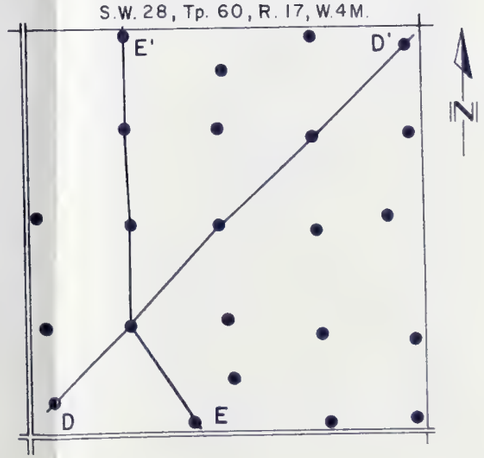
GEOLOGIC CROSS-SECTIONS A - A' B - B' AND C - C'

SCALE —
DATE 1987 JUNE
FIGURE No. C 1

32







LEGEND:

- WATER TABLE WELL
- PIEZOMETER
- STABILIZED WATER LEVEL (1987,06,15)
- RESPONDING WATER LEVEL (1987,06,15)

Alberta ENVIRONMENT — EARTH SCIENCES DIVISION

SUBMITTED	DESIGNED R JACKSON
DATE	CHECKED R RIPPON
APPROVED	DRAWN H O
DATE	CHECKED

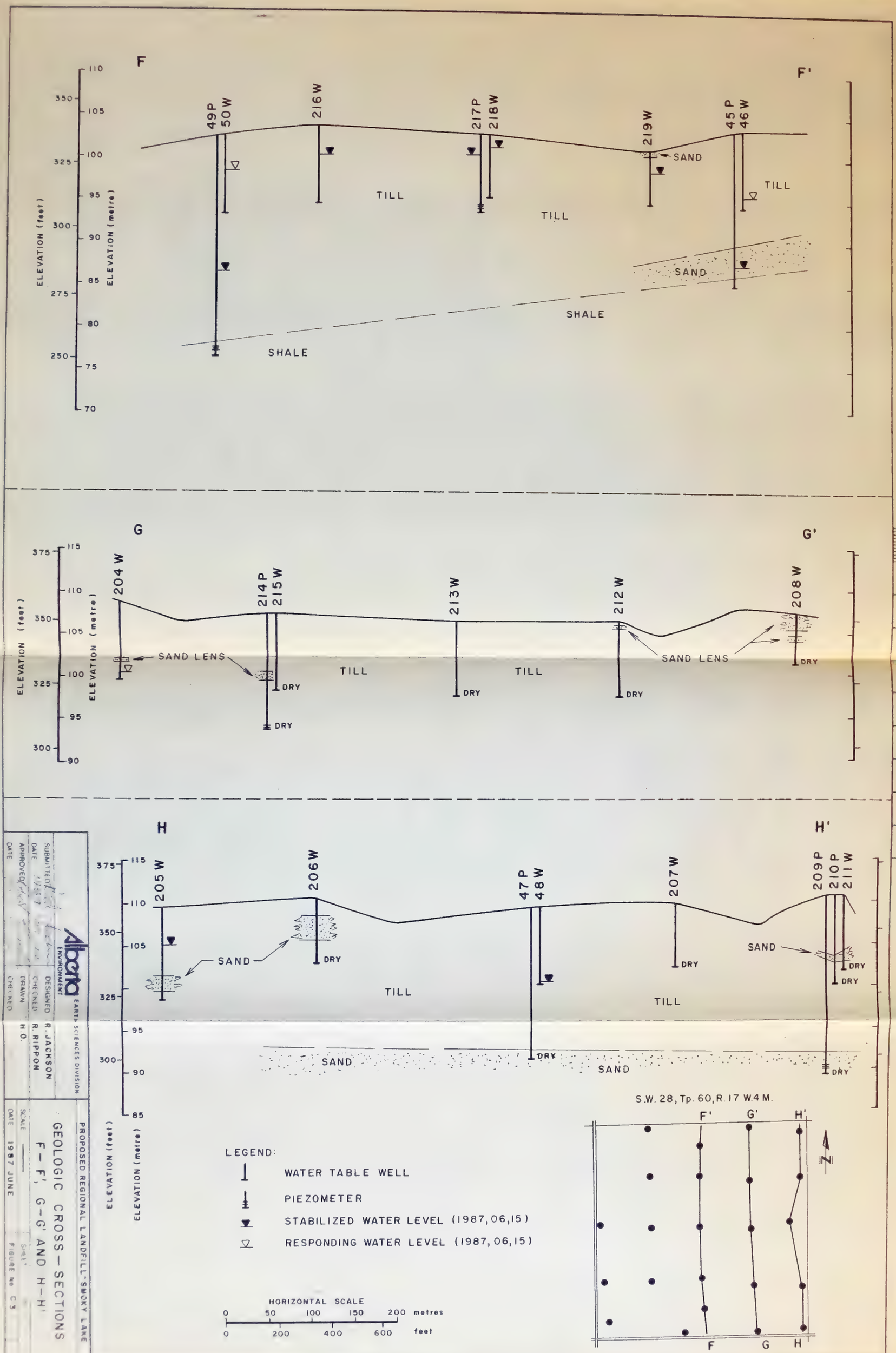
PROPOSED REGIONAL LANDFILL - SMOKY LAKE

GEOLOGIC CROSS-SECTIONS D-D' AND E-E'

SCALE —

DATE 1987 JUNE

FIGURE No. 22


F
F'
49P
50W
216W
217P
218W
219W
45P
46W
TILL
TILL
SAND
TILL
SAND
SHALE
SHALE
ELEVATION (feet)
ELEVATION (metre)
110
105
100
95
90
85
80
75
70
350
325
300
275
250
G
G'
204W
214P
215W
213W
212W
208W
SAND LENS
SAND LENS
TILL
TILL
DRY
DRY
DRY
DRY
DRY
375
350
325
300
115
110
105
100
95
90
H
H'
205W
206W
47P
48W
207W
209P
210P
211W
SAND
SAND
TILL
TILL
SAND
SAND
DRY
DRY
DRY
DRY
DRY
DRY
375
350
325
300
115
110
105
95
90
85
LEGEND:
WATER TABLE WELL
PIEZOMETER
STABILIZED WATER LEVEL (1987,06,15)
RESPONDING WATER LEVEL (1987,06,15)
HORIZONTAL SCALE
0 50 100 150 200 metres
0 200 400 600 feet
S.W. 28, Tp. 60, R. 17 W.4 M.
F'
G'
H'
F
G
H
N
Alberta ENVIRONMENT EARTH SCIENCES DIVISION
SUBMITTED
DATE
APPROVED
DATE
DESIGNED R. JACKSON
CHECKED R. RIPPON
DRAWN H.O.
CHECKED
PROPOSED REGIONAL LANDFILL - SMOKY LAKE
GEOLOGIC CROSS-SECTIONS
F - F', G - G' AND H - H'
SCALE
DATE 1987 JUNE
SHEET
FIGURE No. C3

APPENDIX D

GROUNDWATER DEPTHS AND ELEVATIONS

GROUNDWATER DEPTHS AND ELEVATIONS

Borehole Number	Ground Elev. Metres +	Completed Depth(m)	April 14, 1987 Depth	April 14, 1987 Elev.	April 29, 1987 Depth	April 29, 1987 Elev.	May 15, 1987 Depth	May 15, 1987 Elev.	June 15, 1987 Depth	June 15, 1987 Elev.
43 P	101.42	20.9	14.94	86.48	14.81	86.61	14.78	86.64	14.77	86.65
44 W	101.33	8.7	dry		dry		dry		dry	<92.59
45 P	103.28	16.4	16.24	87.04	16.18	87.10	16.30	86.98	16.21	87.07
46 W	103.30	8.8	8.80	94.50	8.72	94.58	8.14	95.16	7.82	95.48
47 P	109.53	17.5	dry		dry		dry		dry	<92.08
48 W	109.50	8.8	trace		trace		trace		8.68	100.82
49 P	102.45	25.3	15.81	86.64	15.79	86.66	15.79	86.66	15.78	86.67
50 W	102.30	8.7	6.35	94.84	5.83	96.47	4.33	97.97	3.88	98.42
51 W	99.86	7.3	dry		trace		7.22	92.64	6.91	92.95
201 W	99.24	7.4	0.75	98.49	1.09	98.15	2.65	96.59	3.08	96.16
202 P	100.16	15.1	13.06	87.10	13.82	86.34	13.16	87.00	13.05	87.11
203 W	99.34	8.8	dry		dry		dry		dry	<90.55
204 W	108.80	8.8	trace		8.62	100.18	8.59	100.21	8.55	100.25
205 W	109.58	10.5	7.50	102.08	7.09	102.49	6.05	103.53	4.46	105.12
206 W	110.70	7.4	dry		dry		dry		dry	<103.33
207 W	109.93	7.3	dry		dry		dry		dry	<102.68
208 W	107.43	5.7	trace		trace		trace		dry	<101.71
209 P	110.72	20.6	dry		dry		dry		dry	<90.10
210 P	110.68	10.4	dry		dry		dry		dry	<100.32
211 W	110.60	8.8	trace		trace		trace		dry	<101.78
212 W	106.55	8.9	dry		dry		dry		dry	<97.70
213 W	106.65	8.7	dry		dry		dry		dry	<97.91
214 P	107.54	13.5	dry		dry		dry		dry	<94.01
215 W	107.54	8.3	dry		dry		dry		dry	<99.21

W - WATER TABLE WELL P - PIEZOMETER + - ARBITRARY DATUM

N.B. - All depths are from ground surface

APPENDIX E

CALCULATED HYDRAULIC CONDUCTIVITIES

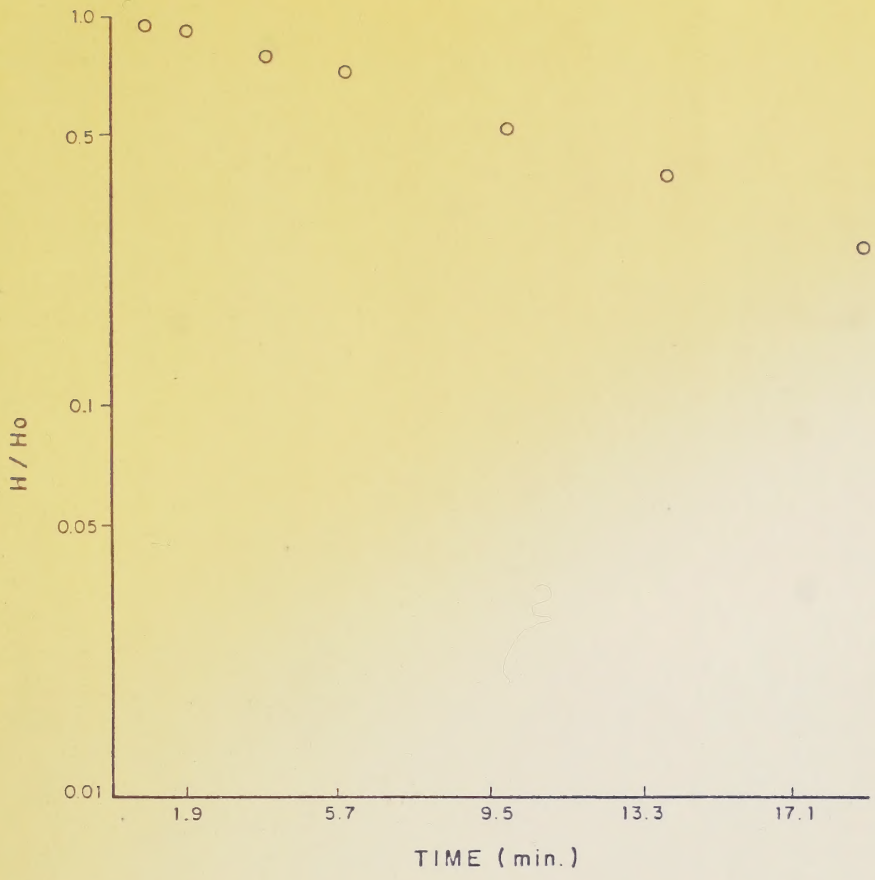
COMPLETION ZONE SUMMARY & CALCULATED HYDRAULIC CONDUCTIVITIES
PROPOSED REGIONAL LANDFILL - SMOKY LAKE

WELL NUMBER	SCREENED INTERVAL(M)	GEOLOGICAL MATERIAL	DATA ORIGIN	HYDRAULIC CONDUCTIVITY k (cm/sec)
43 P	20.3 - 20.9	shale	S	2×10^{-6}
45 P	16.0 - 16.4	sand	IF	
46 W	5.8 - 8.8	clay till	I	
47 P	17.0 - 17.4	sand	dry	
⁂49 P	24.9 - 25.3	sand lens at till-shale contact	S	1×10^{-4}
50 W	5.7 - 8.7	clay till	R	2×10^{-8}
51 W	4.3 - 7.3	clay till	I	
202 P	13.3 - 14.0	sand	IF	
204 W	5.8 - 8.8	clay till	I	
205 W	7.5 - 10.5	clay till/sand lens	S	5×10^{-7}
209 P	20.2 - 20.6	sand	dry	
210 P	9.9 - 10.4	clay till	dry	
214 P	13.0 - 13.5	clay till	dry	
216 W	5.9 - 8.9	clay till	S	7×10^{-6}
217 P	8.4 - 8.8	clay till	S	8×10^{-8}
218 W	4.3 - 7.3	clay till	S	2×10^{-6}
221 P	6.9 - 7.3	clay till	R	3×10^{-9}

S Slug Test
R Recovery Curve
I Insufficient Response (Very Low k)
IF Insufficient fluid

⁂ COMPUTER GENERATED EXAMPLE FOLLOWS

SMOKY LAKE 49P



TIME (s)	WATER LEVEL (m)	DRAWDOWN (m)	H/HO
60	16.72	0.94	0.95
120	16.67	0.89	0.90
240	16.56	0.78	0.79
360	16.48	0.70	0.71
600	16.29	0.51	0.52
840	16.16	0.38	0.38
1140	16.03	0.25	0.25

CONFINED AQUIFER, PARTIALLY PENETRATING CONDITION

$K = 1 \times 10^{-3}$ cm/s

REGRESSION COEFFICIENT

R = -.9983998